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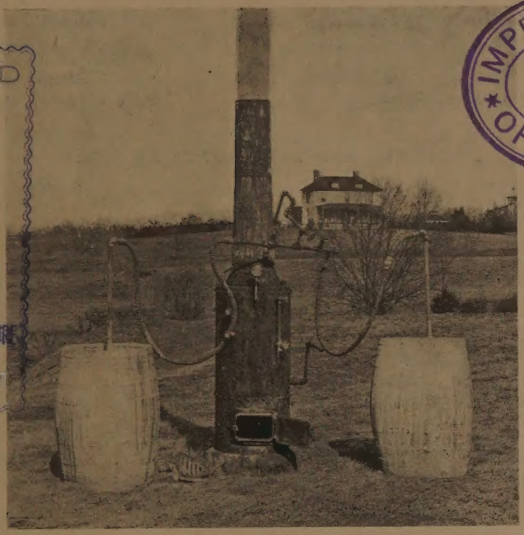

Small steam boiler or "Feed Cooker," a very satisfactory and comparatively inexpensive outfit for preparing concentrated lime-sulphur solution on the farm. Can also be used for many other purposes. This outfit costs about $40.00. With it one man can make five barrels of concentrated solution a day.

The equipment, besides the boiler itself, as illustrated alone in Fig. 3, consists of 3 ¾-inch valves, 2¾-inch elbow, 1 ¾-inch tee, 10 feet ¾-inch pipe, 2 8-foot sections ¾-inch hose, ½ dozen ¾-inch hose clamps.

Preparation of Concentrated Lime-Sulphur Solution on the Farm

BY

G. C. STARCHER

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

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†In coöperation with the Office of Tobacco Investigations, Bureau of Plant Industry, United States Department of Agriculture.

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Preparation of Concentrated Lime-Sulphur Solution on the Farm

The purpose of this bulletin is not to persuade fruit growers to make their own lime-sulphur solution; that is a matter of expediency, which each fruit grower must determine for himself. Its purpose is to place in their hands information that will enable them, if they have decided that home preparation is expedient, to make the solution with as much economy of time and materials as possible, and with reasonable certainty of good results.

Experience of Fruit Growers.—Three hundred fruit growers in the State were asked to give their methods of making the solution and their judgment as to the practicability of home preparation. We received one hundred and eighteen replies: thirty-four are making their own concentrated solution, twenty-four are making the old 15-15-50 wash (for winter use only), forty are buying the commercial concentrated solution, four are using Scalecide, and sixteen gave no information. In the preparation of the material, four used steam, twenty-six used fire, and three used both. The table shows only the results of the home manufacture of concentrated solution, as reported by twenty-seven growers.

TABLE I.

Summary of Reports From Fruit Growers on Home Preparation of Lime-Sulphur Solution.

Formula.	Number Using Each.	Average Baumé Test.	Average Cost per Fifty-Gal. Barrel.	Average Time of Boiling.
50 lbs. burnt lime 100 lbs. sulphur 50 gal. water	13	28.3	$2.96	56 min.
40 lbs. burnt lime 80 lbs. sulphur 50 gal. water	8	26.6	2.25	58 min.
62½ lbs. burnt lime 125 lbs. sulphur 50 gal. water	6	30.3	3.03	52 min.

Experiments at Blacksburg.—In an effort to solve some of the troubles reported by these growers, a series of experiments were conducted at Blacksburg. Three types of apparatus for cooking lime-sulphur were secured, and

also steam from the Station power-house was used, thus duplicating every type of apparatus reported in use in the State.

We used various formulæ, amounts of water, length of time of cooking, different methods of introducing steam heat, and three forms of lime—burnt, ground, and hydrated. In the discussion of these results there is no attempt at technical treatment. Only the practical side of making lime-sulphur solution has been considered.*

Three Formulæ Compared.—The three formulæ below were used. Six boilings of each formula were made.

TABLE II.

Comparison of Different Formulæ in Preparation of Lime-Sulphur Solution.

Pounds Lime.	Pounds Sulphur.	Gallons Water.	Average Baumé Test When Cold.	Average per cent Clear Solution.
62½	125	50	31 to 32.5	56.5 at 24 hrs.
50	100	50	26 to 27	67.6 at 24 hrs.
40	80	50	23 to 24	68.7 at 24 hrs.

These results show that the per cent of clear solution increased as the Baumé reading decreased. Our results show that the 50-100-50 formula is the most practicable for the average equipment; that any attempt to get a Baumé reading above 27° made the sludge less valuable; and that the use of the 40-80-50 formula resulted in a loss in labor. We would, however, prefer the 40-80-50 formula to any formula above 50-100-50.

Burnt vs. Hydrated Lime.—In all cases just twice as much sulphur as burnt lime was used. When hydrated lime was substituted for burnt lime

*The following are definitions of the terms used in this Bulletin:

Concentrate, or Clear Solution.—The amber-colored solution which remains at the top of the vessel after the finished material has stood for some time.

Sludge.—The dark part of the solution which will pour from the vessel freely, and pass through a strainer readily.

Crystals.—These may be found at top, sides, or bottom of vessel, and have the appearance of mush ice, except in color.

Sediment.—Uncombined lime, sulphur, or impurities at bottom of vessel.

Paste.—Sludge at bottom of vessel that has assumed a pasty nature after long boiling.

Burnt Lime.—The fresh burned lime as it comes from the kiln.

Ground Lime.—The above form, finely ground.

Hydrated Lime.—Burnt lime slaked with water, dried and shipped in paper-lined barrels, or paper sacks.

allowance was made for the water of slaking; thus, if the formula called for 62½ pounds of burnt lime, 83 pounds of hydrated lime were used; when 50 pounds were called for, 66 to 70 pounds were used; and when 40 pounds were called for, 54 pounds were used. In other words, about 33 per cent in weight of hydrated lime was added in each case, this representing the water in hydrated lime.

FIG. 1.—A 75-gallon jacketed kettle in which 35 to 45 gallons of concentrated solution can be prepared. Cost, about $15.00. Economical and satisfactory.

The following table shows the relative cost of a barrel of concentrated lime-sulphur solution when burnt lime and hydrated lime are used. The estimate is based on the first or wholesale cost of the material, as follows:

Burnt lime, cost at the kiln 65 cents per barrel of 180 pounds net.

Hydrated lime, cost 74 cents per barrel of 150 pounds net.

Sulphur, in 100-pound bags, cost $1.75 per hundred pounds.

Flour of Sulphur, in barrels, cost a little more, and was no better than that in sacks.

TABLE III.

Relative Cost Per Barrel of Concentrated Lime-Sulphur Solutions, Using Burnt and Hydrated Lime.

Formula Used.	Form of Lime.	Test on Baumé Spindle.	Total Cost of Materials, Not Including Freight or Labor.
62½-125-50	Burnt	32	$2.41
62½-125-50	Hydrate	32	2.57
50-100-50	Burnt	26.5	1.93
50-100-50	Hydrate	26.5	2.07
40-80-50	Burnt	24	1.54
40-80-50	Hydrate	24	1.66

The use of lime in the hydrated form increased the cost of a barrel of concentrated solution from twelve to sixteen cents. On the other hand, the hydrate is much more easily handled, the danger from improper slaking is eliminated, and, according to Table VII, there is not so much loss from exposure to the air.

Ground burnt lime gave such poor results in every case that we have made no record of its use. It is difficult to slake and has nothing to recommend it above either of the other forms.

Per cent of Sludge.—The table below shows that burnt lime gives a greater per cent of sludge than hydrated lime, but shows a higher per cent of clear solution when filtered, and the sludge will probably pass through the spray nozzle more freely than that from the hydrated lime.

TABLE IV.

Per cent of Sludge in Solutions Made From Burnt and Hydrated Lime.

Formula.	Lime.	Method of Cooking.	Per cent Concentrate Before Filtering.	Per cent Concentrate After Filtering.	Remarks.
50-100-50	Burnt	Fire-feed cooker	57.1	96.8	Solution filtered after standing 24 hrs.
50-100-50	Burnt	Fire-feed cooker	56.1	97.2	Solution filtered after standing 24 hrs.
50-100-50	Burnt	Fire-feed cooker	50	96.5	Solution filtered after standing 24 hrs.
50-100-50	Hydrate	Fire-feed cooker	61.4	95.5	Solution filtered after standing 4 hrs.
50-100-50	Hydrate	Closed steam coil	74.4	95.5	Solution filtered after standing 24 hrs.
50-100-50	Hydrate	Perforated steam coil	68.2	95	Solution filtered after standing 24 hrs.

The above table shows that the final amount of clear solution varied but little in the three methods of cooking the hydrate lime solution, but that with the same method of cooking the burnt lime had 1.7 per cent more clear solution than the hydrate.

Value of Sludge.—A number of experiments were made in an attempt to discover some easy means of separating the clear solution from the sludge, but with no practical result. The replies from the fruit growers show that nearly all consider the sludge valuable as a marker. Our filtration table shows it to be almost as valuable for spraying purposes, gallon for gallon, as the clear solution. It is much to be preferred as a marker to an addition of milk of lime to the clear solution.

In no case was the sludge found difficult to handle if the proper amount of water was used, and the material was boiled not less than forty-five minutes or more than sixty minutes. If an insufficient amount of water was used, or boiling was stopped too soon, the sludge crystallized freely. If boiling continued more than an hour, the sludge assumed a pasty nature. This was especially true when the final amount of solution was allowed to fall below the amount called for in the formula.

Apparatus for Cooking.

Fig. 1 shows a seventy-five-gallon jacketed kettle with wooden cover, for use with wood or coal. There is little loss of heat by radiation with this apparatus. We found it very satisfactory. Thirty to forty-five gallons of concentrated solution can be made in this vessel at one time. The outfit as illustrated will cost about fifteen dollars and can be bought of any large mail order or farmer's supply house. The outfit can be taken to the orchard or used in a shed. It will last for many years.

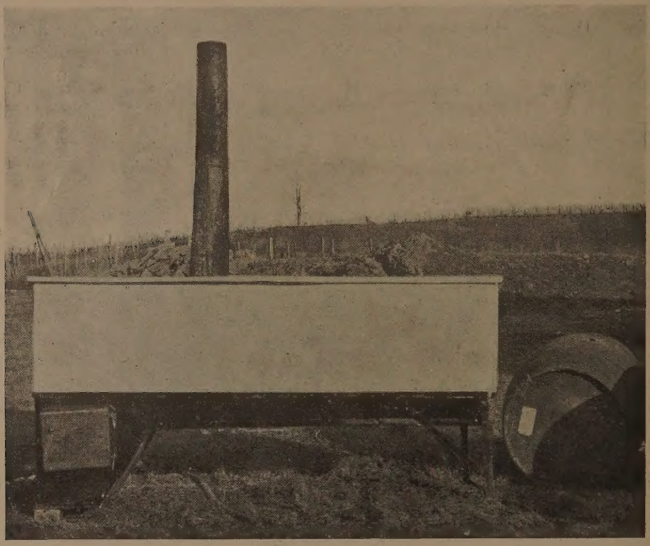

Fig. 2.—A stock feed boiler in which 50 gallons of concentrated solution can be prepared. Slightly more convenient than that in Fig. 1, and gives equal results, but costs somewhat more.

Fig. 2 shows a stock feed boiler with metal cover, for use with coal or wood. Fifty gallons of the concentrated solution can be made at one time. This should be used in a closed house, as the metal surface allows great heat radiation. This very satisfactory outfit for small operations will cost about fifteen dollars. It will last for years if given good care. This outfit was purchased from B. F. Freeland Sons Co., Sturgis, Michigan. Other firms make similar cookers. This type of cooker is more convenient than the one described above, otherwise they give about the same results.

The front cover illustration is a small steam boiler or "feed cooker," connected with two barrels by rubber hose and one-half-inch pipe, with perforated coil or perforated two or four way tee in the bottom of the barrels. Live steam is used. Two half barrels of material can be boiled at one time. Two other barrels could be attached so the operator could be emptying the prepared solution and preparing another lot for cooking while the first is boiling. One man can make five barrels of concentrated solution with this outfit in ten hours. We prefer it to any other apparatus used. Excellent results were secured with the above outfit with ten to twenty pounds of steam.

This boiler costs from thirty to forty dollars and can be used in many other ways on the farm. The outfit is so light that two men can load it into a wagon, and it is so simple that it can be used anywhere. It should be equipped with pressure gauge, water gauge, and a special water pump for filling boiler, which usually comes with the boiler; a barrel spray pump would do. We connected our high-pressure water works with the boiler and let the water in as needed. If the fruit grower has water works with a fifty-foot head, that pressure is sufficient. This boiler can be bought of Griffith & Turner Company, of Baltimore, Md., and other large supply houses.

The equipment, besides the boiler itself, as illustrated alone in Fig. 3, consists of 3 ¾-inch valves, 2¾-inch elbow, 1 ¾-inch tee, 10 feet ¾-inch pipe, 2 8-foot sections ¾-inch hose, ½ dozen ¾-inch hose clamps.

Steam from the Experiment Station power-house was also used; but as it was conveyed under ground a distance of eighty feet through uninsulated pipes, the steam was so low in temperature and so wet that poor results were obtained.

A closed coil for steam, with a valve on the free end, which enabled us to get considerable pressure in the coil by merely allowing the condensed steam through, was tried, but no advantage was noted over the perforated coil. The solution heated more slowly and boiled over the sides of the container more readily than when the perforated coil or tee was used. The perforated coil and tee gave better agitation of the lime and sulphur before it went into solution in every case.

We did not use more than 40 pounds steam pressure at any one time, and much of our cooking was done with 15 to 20 pounds pressure.

Suggested Outfit for Small Commercial Operations.—Fig. 3 shows a plan of arranging a home steam cooking plant. The timbers used are heavy enough to support a second story, thus enclosing the cooking outfit. The lumber specifications given below can be modified if only an open platform, as illustrated, is desired. The placing of the steam boiler, tank, pump, scales,

and the arrangement of the four barrels for cooking, and the four empty barrels for the prepared solution, are not intended to be ideal. The source of the water supply, lay of land, and other factors will have to be taken into account. Usually the boiler will be placed beneath the platform; it is shown outside here only for purposes of illustration. A tank for holding a reserve supply of water, or for mixing enough solution to fill the spray tank, could be substituted for the four barrels or in addition to them.

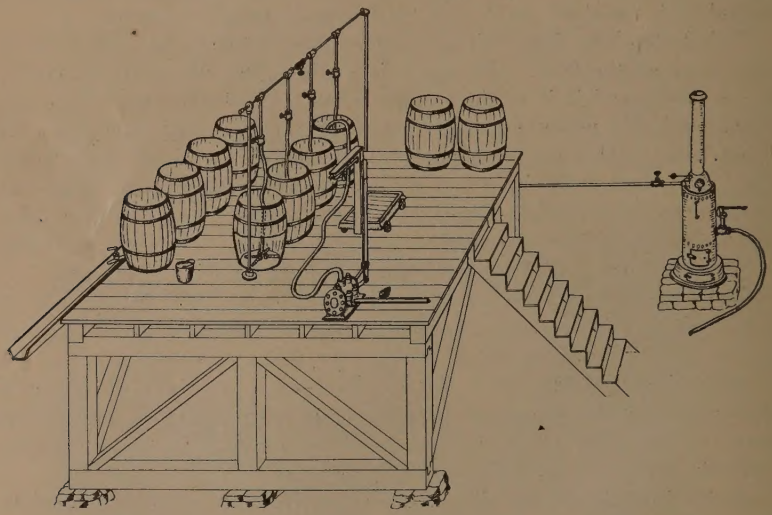

FIG. 3.—An inexpensive steam outfit for preparing lime-sulphur solution on the farm. The small steam boiler costs about $35.00. It may be placed beneath the platform, and is shown outside here only for the purpose of illustration. Two barrels of solution are boiling while the other two are being prepared. Note the scales for weighing materials; the boat pump for drawing up water from the spring below; the four water barrels, which may be filled while the solution is boiling, so as to be ready for immediate discharge into the spray tank. The total cost of this outfit should not exceed $80.00. With it one man can prepare 250 gallons of concentrated solution in ten hours.

The outfit as illustrated is 12 feet square and will take, besides the small boiler described above, the following bill of lumber, iron pipe, valves and hose:

2 pieces 4 in. x 8 in. x 12 ft. long for end of floor boards.
5 pieces 2 in. x 6 in. x 12 ft. long for floor supports.
4 pieces 6 in. x 8 in. x 12 ft. long for top and bottom sills.
6 pieces 6 in. x 6 in. x 4½ ft. long for uprights.

8 pieces 2 in. x 6 in. x 6 ft. long for braces.
2 pieces 1 in. x 12 in. x 10 ft. long for stairway.
25 ft. 1 in. x 8 in. for steps for stairway.
3 pieces 1 in. x 4 in. x 12 ft. long for trough for solution.
25 to 40 ft. ¾-in. iron pipe, depending on position of boiler.
7 valves ¾ in.
24 ft. steam hose ¾ in.
20 ft. 1-in. rubber hose for conducting water from tank pump to cooking barrels.
10 ft. 1½-in. suction hose leading from tank pump to water supply.
1 doz. 1-in. hose clamps.
2 1½-in. hose clamps.
1 doz. ¾-in. hose clamps.
4 3-way joints for ¾-in. pipe.
2 elbow joints for ¾-in. pipe.
4 4-way perforated tees, with perforations on under side of pipes, for introducing steam into barrel ¾-in. pipe.

The upright pipe connecting with the tee in the bottom of barrel should extend eighteen inches above top of barrel, and connects with a six-foot section of steam hose. In this way the tee can be lifted out of barrel when the cooking is done, and can be used to stir the materials while cooking.

It is impossible to say what the cost of the materials for this outfit would be, but certainly not far from $80.00. But if the building and steam supply are already available, and empty barrels and weighing scales are on hand, the cost of the rest of the apparatus can be brought to less than $30.00. The steam boiler outfit illustrated on the front cover is, of course, the simplest outfit possible.

Fig. 4 illustrates the Baumé hydrometer, or spindle, and a glass cylinder in which to pour the solution for making the test. Positive knowledge of the strength of a lime-sulphur spray is so necessary that we give it first place in the steps necessary to success with either the commercial or home-made solution. Spindles can be purchased of Bausch & Lomb, Rochester, N. Y., E. C. Tyson, Floradale, Pa., Arthur H. Thomas Co., Philadelphia, Pa., or perhaps through your local druggist. It will cost about $1.00 as illustrated.

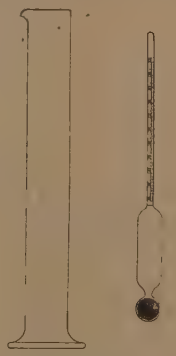

Fig. 4.—Baumé spindle, or hydrometer, and a glass cylinder for making test. Satisfactory results can not be expected with either home-made or commercial solutions unless they are first tested and diluted accordingly.

The table below is adapted from bulletin No. 330, New York Agricultural Experiment Station, Geneva, N. Y., and is the one in general use in this state.

Table V.

Dilutions for Dormant and Summer Spraying—Lime-Sulphur Solution.

For strong mixtures for the scale, the DILUTED PREPARATION should test about 4.5 degrees B.; and for summer spraying of apples about 1 degree B. Using these figures as basis, the table below has been calculated, which shows the dilution required for a wide range of densities.

Reading of Hydrometer.		Amount of Dilution. Number of gallons of water to one gallon.	
Degrees Baumé.	Specific Gravity.	For San José Scale. (Winter Strength.)	For Summer Spraying of Apples.
35 degrees	1.3181	1 to 9	1 to 45
34 "	1.3063	1 " 8 3-4	1 " 43 1-4
33 "	1.2946	1 " 8 1-4	1 " 41 1-2
32 "	1.2831	1 " 8	1 " 40
31 "	1.2719	1 " 7 1-2	1 " 37 3-4
30 "	1.2608	1 " 7 1-4	1 " 36 1-4
29 "	1.2500	1 " 6 3-4	1 " 34 1-4
28 "	1.2393	1 " 6 1-2	1 " 32 3-4
27 "	1.2288	1 " 6	1 " 31
26 "	1.2184	1 " 5 3-4	1 " 29 1-2
25 "	1.2083	1 " 5 1-4	1 " 27 3-4
24 "	1.1983	1 " 5	1 " 26
23 "	1.1885	1 " 4 1-2	1 " 24 1-4
22 "	1.1788	1 " 4 1-4	1 " 22 3-4
21 "	1.1693	1 " 3 3-4	1 " 21 1-4
20 "	1.1600	1 " 3 1-2	1 " 19 3-4
19 "	1.1507	1 " 3 1-4	1 " 18 1-4
18 "	1.1417	1 " 3	1 " 17
17 "	1.1328	1 " 2 3-4	1 " 16
16 "	1.1240	1 " 2 1-2	1 " 15
15 "	1.1153	1 " 2 1-4	1 " 14
14 "	1.1067	1 " 2	1 " 12 3-4

The Baumé Spindle (Hydrometer), marked in degrees, must be used when diluting with the above table.

Thirty-three degrees Baumé is what is termed the "Standard" strength for the Concentrated Solution.

Please Note that the recommendation is 1 *to* 9, not 1 *in* 9. Some growers have failed to observe the distinction.

Relative Cost of Concentrated Lime-Sulphur Solution and the Old 15-15-50 Lime-Sulphur Wash.—The cost of the lime and sulphur here given is the delivered price of these materials.

Formula.			Cost of Lime.	Cost of Sulphur.	Labor and Fuel per Barrel.	Cost per Barrel of Spray.
Lime.	Sul.	Water.				
15	15	50	.085	$0.30	.175	$ .56
60	120	50	.34	2.40	.175	.48

This table shows a difference in the cost of a barrel of diluted solution ready for winter spraying for San José scale, of only eight cents in favor of the concentrated solution, but it should be remembered that the wash can only be made while the spraying is being done and must be used at once. The concentrated solution, on the other hand, can be made on rainy days or in early morning or late afternoon of spraying days, or at other leisure times, and stored until ready for use.

Keeping Lime.—Quick burnt lime will keep for a considerable time if put up in paper-lined barrels, and when stored in an air-tight box. It will also keep well if it is slaked and covered with water.

The table below shows the analyses of the three forms of lime used in our experiments. All three forms of lime came in paper-lined barrels, arrived at the same time, and were stored in the same room. The burnt lime was purchased from the Eagle Rock Lime Co., of Eagle Rock, Va., and was found to be practically 98 per cent calcium oxide. The hydrated lime was purchased from the Security Cement and Lime Co., Hagerstown Md. This sample, as shown by analysis, contains 2 per cent more inert material than the burnt lime. It also contains a slight amount of calcium oxide as such and about 4 per cent of calcium carbonate. The sample is, however, a first-class commercial product. This difference noted for inert material probably accounts for results shown in Table IV. All samples had been on hand two months before the analyses were made.*

TABLE VI.

Analyses of Limes.

Form of Lime.	Time Exposed to Air.	Insoluble Residue.	Fe_2O_3 and Al_2O_3	CaO (Lime).	MgO (Magnesia).	Co_2	H_2O by Difference.	Total.
No. 1. Burnt	Not Exposed	0.33	1.28	97.88	Trace	1.15	0.36	100
No. 2. Burnt	Exposed in dry room 3 days	0.38	0.88	83.20	Trace	1.19	14.35	100
No. 3. Hydrated	Not Exposed	2.40	1.20	69.8	Trace	1.84	24.76	100
No. 4. Hydrated	Exposed in dry room 60 days	2.16	0.96	76.52	Trace	7.49	21.87	100
Ground Burnt	Not Exposed	1.30	1.20	93.20	Trace	1.35	2.95	100

*Analyses by courtesy of Dr. W. B. Ellett and H. H. Hill, Dept. of Chemistry, Va. Ex. Sta.

The sample of burnt lime (No. 1) that was kept in a paper-lined barrel in a dry room for two months contained less than two tenths of one per cent of carbon dioxide, but the same sample (No. 2.) took up more than one per cent of carbon dioxide in three days after the barrel was opened, or one hundred times as fast as it had in the closed barrel. The hydrated sample (No. 3.) shows twelve times as much carbon dioxide, but less than two per cent after being slaked, dried and ground and kept two months. The sample of hydrated lime (No. 4) which was exposed to air sixty days has only 7.49 per cent of carbon dioxide, or an increase of 5.65 per cent in sixty days, or

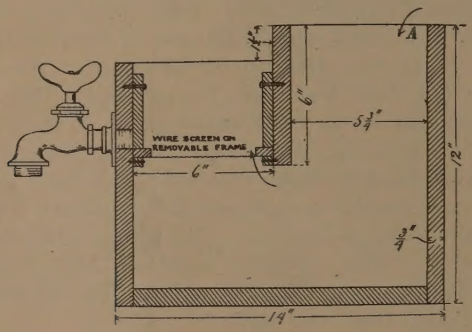

FIG. 5.—A type of strainer designed by J. P. Stewart, of the Pennsylvania Experiment Station, for lime-sulphur or other spray materials. The liquid enters at "A," passes upward through the screen and is carried where desired through a hose attached to the spigot. The coarse particles thus fall away from the screen instead of accumulating on it. Any solution retained in the sediment may be secured by running through it the water required for the next boiling.

only four and one half times as much when exposed twenty times as long as the burnt lime. It should be remembered that all the lime in a barrel of burnt lime is exposed as soon as the barrel is opened because of the large air spaces between the lumps, while in the hydrated lime only the surface layer is exposed on account of the material being a closely packed powder. One sample (No. 4.) was taken from the exposed surface of hydrated lime, which was not a fair test. The lime three inches below the exposed surface was probably almost as free from carbon dioxide as an unopened barrel.

This comparison of the analysis of the several forms of lime strengthens our conviction that hydrated lime, when it can be bought at a reasonable price, is preferable for the preparation of lime-sulphur solution.

IMPORTANT POINTS IN PREPARATION

Foaming of the solution when boiling begins may largely be prevented by the addition of a few pounds of salt. This also makes the lime and sulphur go into solution quicker. Boil not less than forty-five nor more than sixty minutes.

Testing for strength with the Baumé spindle should only be done after the solution has cooled. The boiling solution will not show as high reading as it will when cold, by from one to three degrees. If, however, the solution is to be used immediately allow for one or two degrees higher reading when making the dilution.

Sediment is due to the following causes: lumpy sulphur, which should be run through a sieve, not enough water, impure lime, air slaked lime, improperly slaked lime, irregular boiling. It should be strained out through two thicknesses of wire fly screening, or the strainer shown in Fig. 5. The *sludge* that passes through the strainer may be disregarded.

Storage.—Unless used the day it is made, which is often the most practicable method, concentrated lime-sulphur solution should be stored as soon as made in air-tight barrels. If open vessels are used for storage a thin film of oil on the surface will prevent deterioration.

Mixing Ingredients.—If burnt lime is used it should be slaked with hot water, and care must be taken to use enough water to prevent burning, and yet not enough to drown the lime and thus prevent slaking; slaking is more easily done with hot water. The sulphur may be mixed to a paste and then added to the lime solution, or it may be added dry and mixed afterward. Hydrated lime can be added after the sulphur, before the sulphur or with the sulphur with equally good results.

SUMMARY

1. Direct fire heat and steam were of about equal value in cooking the material, both from the standpoint of economy and from the test, but steam heat is much more easily controlled. A small steam boiler, costing about $35.00, is one of the most practicable outfits for all except the largest commercial orchards.

2. Burnt and hydrated lime gave about equal results, but the hydrated lime is easier to handle, will keep longer without becoming carbonate, and gives a higher per cent of clear concentrate. Ground quick lime was not found desirable.

3. Sicilian sulphur in bags and the commercial ground sulphur gave equal results.

4. An attempt to get a high Baumé reading is not desirable. The 50-100-50 formula gave best results, and the 40-80-50 next, both being preferable to the 62½-125-50 formula.

5. Sludge was found to be almost as valuable for spraying as the clear solution, when the solution has been properly made, and its presence in the home-made solution is no disadvantage. The dark sludge from properly made lots was found to contain as high as 93 to 94 per cent clear solution, and it did not go to a paste after standing exposed for weeks. If the commercial concentrated solution is purchased, however, insist that it be free from sludge.

6. Home-made concentrated lime-sulphur solution costs about one-half as much as the commercially prepared, at current prices. It requires a little more care in its use, since it is not usually as constant in strength as the best commercial brands. Many fruit growers should find it more economical to make the solution at home; others will find the commercial solution more expedient under their conditions.